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ABSTRACT

The telecommunications sector is characterized by massive structural changes due to changes in technology as well as in the regulatory environment. Research and development activities become more and more important for the development of the industry as they determine the competitive position of firms and nations to a large extent. Both the equipment manufacturer and the network service provider depend on their technological competence. In the past, the national research and development systems of the industrialized countries in the telecommunications sector developed separately, and the systems that emerged were quite different from one country to another. With the liberalization of the telecommunications markets and the increasing international competition (so far mainly in the equipment sector), the different national research and development systems have come under pressure and begun to change. This paper presents theoretical and methodological remarks; provides an international comparison of research and development expenditures and patents; presents the characteristics of national research and development centers in Japan, the United States, France, the United Kingdom, and West Germany; and discusses the implications of current developments for future competitiveness in the international market. (GL)

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RESEARCH AND DEVELOPMENT IN TELECOMMUNICATIONS

- AN INTERNATIONAL COMPARISON -

by

Thomas Schnöring*

Preliminary version of a paper prepared for the Telecommunications Policy Research Conference, Airlie House, Oktober 1 - 3, 1989. Not to be quoted without permission of the author.

* The paper is based on a research project of the WIK and the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe. I would like to thank H. Grupp, W. Neu and K.-H. Neumann for many valuable discussions. Remaining errors are solely mine.

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Research and Development in Telecommunications - an International Comparison[1]

1. Introduction

The telecommunications sector is characterized by massive structural changes due to changes in technology as well as in the regulatory environment. Research and development activities (R&D) become more and more important for the development of the industry. They determine the competitive position of firms and nations to a large extent. Both the equipment manufacturer and the network and service provider depend on their technological competence. In the past, the national R&D-systems of the industrialized countries in the telecommunications sector have developped seperately. The systems that emerged were quite different from one country to the other. With the liberalization of the telecommunications markets and the increasing international competition (so far mainly in equipment sector) the different national R&D systems came under pressure and began to change. How do these national R&D systems look like? What are the advantages and disadvantages? How big is the R&D input of countries and firms and what is the output? What conclusions can be drawn from this for the future competitiveness in the international markets? These are questions the paper is about.

2. Some theoretical and methodological remarks

2.1 Definitions, Demarkation and Data Sources

Although considerable progress has been made over the past years in the measurement of scientific and technological activities, there is no unique and superior measure of innovative activities and technological levels. Each has its strengths and weaknesses[2], therefore we have used a range of statistical indicators (R&D expenditure, patents, scientific publications etc.) and complemented them with a series of interviews in each country. The judgements of the experts should help to bridge the inadequacy of the statistical indicators. The research project was a collaborative work of WIK and Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe[3].

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1 The paper is based on a research project of the WIK and the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe.

2 Grupp, H. (ed.) (1986), Problems of measuring technological change, Köln.

3 Grupp, H., Schnöring Th. (ed., forthcoming), Forschung und Entwicklung im Telekommunikationssektor - internationaler Vergleich mit zehn Ländern

Definition of the subject "R&D in telecommunications" cannot be estabilished unassailably. The demarcation used tries to deal consistently with diverse statistics and data sources and the definitions these contain. So what is telecommunications R&D? After perusal of various classification systems and the relevant literature, "Telecommunications" has been defined as a combination of 11 sub areas (compare Table 2/1). Other demarkations are conceivable.

Table 2/1: Subfields of Telecommunications R&D

acronym	heading	contents
TH	information and communication theory artificial general intelligence	information theory, speech synthesis, information and communication theory
WI	grid-based (wired) communication	grid-based transmission systems (incl. cables), telephone traffic (incl. telephone sets, private branch exchanges), switching, transmission technology electromagnetic converters (mouth piece), multiplexing for analog systems
RA	radio technique	antennae, aerial transmitting/receiving, radio communication systems (incl. satellites), noise reduction, control of oscillations, secret radio traffic
PI	general picture transmission	TV systems, image processing and recognition, cable systems for picture transmission, closed circuit TV
IM	image communication	facsimile (standing picture communication), moving picture communication (picture telephone)

DI	digital transmission	pulse technique, digital transmission (incl. telegraphy) analog to digital converter, pulse code modulation, encoding, digital transmission systems digital networks
FI	optical (fibre) communication	lasers for communications, optical cables, light control, light modulation, optological elements, optical analog to digital converters, optical semiconductor elements
HF	high frequency telemetry	wave guides, radionavigation, radar systems and equipment
ME	telemetering	traffic telemonitoring, telecontrol, telemetry
OE	other equipment (if not included elsewhere)	scanners, electrography, magnetography, data terminals, speech recognition apparatus, printers, plotters, electronic displays, holography, information storage
SO	services, software, policy	services, electronic mail, politics (laws, standards, norms) frequency administration, electronic media, TV systems applications, telecommunications in management, applications

Owing to lack of data, research statistics cannot differentiate between the individual fields within telecommunications. Consequently, R&D expenditure and R&D personnel can be quoted only for the field as a whole. Military-related R&D data are especially difficult to distinguish from civil data.

Delimination of the individual sub areas in telecommunications with the aid of patent symbols or classification symbols from the INSPEC bibliographical databank[4] used is a more accurate way of proceeding than using the verbal description in Table 2/1. Wherever possible, an entire sub area defined by a classification symbol is allocated to one field only. In those cases, where this appears to be impermissible from the professional standpoint, apportionment is done by logical links with key words.

Detailed analysis of R&D finances continues to be outstandingly problematical. At the heart of the matter is the so-called "Frascati-Definition" of R&D which states the following: "Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications"[5].

Activities to be excluded from R&D are teaching and training, scientific and technical information services and data collections, testing, standardisation and normalisation plus economic activities directed towards marketing (innovation) and production. The construction of prototype and pilot plants is to be included, design and building work only to the extent that they are required for the R&D phase and not the production process.

There is some argument as to whether software origination ("programming") equates to an R&D activity. On the one hand, the "state-of-the-art" in "software technology" is often improved, thereby elevating software generation to the status of a genuine R&D service. On the other hand, frequently only well established programming procedures are employed for writing and improving programs which cannot be rated as an R&D characteristic.

The most important supranational databank on R&D is managed by the OECD. From this databank, at the highest disaggregation stage, the R&D expenditure of economic sector ISIC 3832 can be obtained which include manufacture of radio and television sets and this is therefore too broad a concept for the basic definition here. So national sources of the most disparate kind need to be involved. Owing to gaps and inconsistencies in mostly heterogeneous data material and owing to nationally differing demarcations, examination and assessments of the material was unavoidable.

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4 INSPEC (Information Services for Physics and Engineering Communities) is a British bibliographical databank.

5 OECD (ed.) (1981), The measurement of scientific and technical activities, "Frascati Manual", Paris, p.25

Overall, consistency trials show that the statisical data compiled are indeed reliable but display many gaps and inconsistencies.

Publications and patents can be interpreted as output indicators of R&D. ISI has analysed patent applications in the telecommunications sector at the US (USPTO) and at the German/European patent office (DPA/EPA) from 1975 to 1986 based on different databanks.

Apart from patent databanks which usually rely on official documents, bibliographical databanks are being set up in the private sector. The companies concernd have to prepare their own data files containing information on authors, subjects, addresses and key words. In term of consistency and completeness, therefore, the data held on bibliographical databanks are not of the same high level as comparable patent databanks. The choice of databank is thus critical to the investigation. Four internationally recognized bibliographical databanks were checked for their technical completeness. It was evident that the British databank INSPEC was clearly superior to other databanks. Therefore, INSPEC was chosen for biblographical analysis of publications in telecommunications from 1973 to 1987.

However carefully indicators are investigated and compiled, much important information about a national R&D system can not be gathered this way. A substantial part of the investigation was therefore an international comparative field investigation in which prominent R&D participants in the telecommunications field were questionned personally. The survey was conducted in 1988/89.

In the paper we present some results for the US, Japan, Germany, France and the UK. These five countries represent roughly 55 % of the world telecommunications market. Originally, the study was carried out for five countries more[6].

2.2 The Model

In our analysis, a national R&D-system consists of four sectors: the network and service providers (carriers), the equipment manufacturers, the government sector, and the universities and other non-profit research institutions. These sectors carry out and/or finance R&D. The government sector mainly finances R&D for industrial and defence policy reasons, while the research institutions do research financed by the government and other sectors.We analyse the division of labour between these groups of actors and the dynamics of the system.

[6] Italy, Sweden, Spain, Netherlands, South Korea

We assume that there exist distinct national R&D-systems which means for example that the intra-national flow of information and other types of intra-national interaction in the R&D-process is significantly closer than on the inter-national level. This assumption was certainly correct in the old world of telecommunications. It is still plausible because of the distinct history of each national network and the network character of telecommunications. But it is beginning to erode by the internationalization of manufacturers on the one hand and the liberalization of the equipment market on the other. International R&D collaboration among telecommunications manufactures is increasing rapidly, especially in Europe, and it is one objective of the telecommunications policy of the European Commission. The future will show to what extent collaborative R&D among competing firms and nations can work in the telecommunications sector.

For an economic analysis of the R&D system in the telecommunications sector the relation of carriers and manufacturers - vertical integration versus separated firms - is of special interest. Different arguments are brought forward about how this relation influences the amount, the orientation and the efficiency of R&D. First, a vertically integrated system can better appropriate the results of R&D activities and will therefore invest more in R&D. The argument refers especially to research activities where one could not predict whether the service or the manufacturing side will be the principal beneficiary of the R&D activity. Second, in-house R&D is more efficient because of the superiority of intra-organisational methods of communication and other economies of scope between R&D for networks and services, and for manufacturing[7]. Both arguments have some merit and favour vertical integration. In United States versus AT&T both arguments were used by Bell in defence of the vertical integrated Bell System[8].

But there is also some danger in vertical intergration. The R&D laboratories may acquire a sole orientation towards the needs of the carrier's division of the company which may be disadvantageous for the export business of the manufacturing division because their other customers may have different needs. This is especially a problem when the demand of the carrier's division is relatively small compared to the R&D overheads

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7 See for example, Olley, R. E.(1982), The process of Technology Transfer and Application in Telecommunications: A case study, in: Sahal, D. (ed.), The transfer and utilization of technical knowledge, Lexington, p. 175 - 203

8 Mowery, D.C. (1987), Forecats of the impact of divestiture on Bell Telephone Laboratiories: An Assessment, paper prepared for the Telecommunications Policy Research Conference, Airlie House, Sept. 27-30, 1987, p.5; Noll, R.G., Owen, B.M. (1987), United States v. AT&T, The economic issues, Stanford University, California, Studies in Industry Economics, Discussion Paper No. 140, p. 58

attendant to the development of new products[9]. On the other hand, it may be a disadvantage for the carrier's division to be solely bound to the company's own R&D and manufacturing division. Upstream R&D rivalry may prove to be a better choice from the carrier's point of view because it reduces the risk to pick an inadequate equipment. This argument gains influence in times of increasing technological change.

The arguments of economic theory remain contradictary and it becomes an empirical question which industry structure is best for R&D. Empirical evidence of the past seems to strengthen the first two arguments and the case for vertical integration. The Bell System and Northern Telecom have been vertically integrated and in many European countries as well as in Japan we observe special relations and/or joint R&D activities between network providers and national manufacturers. But for different reasons these preferential relations have loosened in some countries. The US divestiture has separated the market of the BOCs from AT&T. Some national carriers in other countries started to introduce competing systems in their networks. National carriers follow more and more a policy of second sourcing. Increasing R&D costs force carriers and manufacturers - especially in Europe - to go international and by this loosen their traditional preferential relation.

Looking at countries with separated carriers and manufacturers one can distinguish two basic models when it comes to R&D for complex equipment systems like central office switches. In the first model, the national carrier is the leading actor. It does a lot of R&D itself, it is engaged in joint R&D projects with its traditional national suppliers and it finances most of the manufacturers' R&D activities directly by development contracts. The actual procurement of the equipment is done separately from the development. A limited number of national manufacturers which usually have been involved in the development of the system compete for contracts. This model has advantages and disadvantages. First, it is similar to the model of vertical integration with respect to economies of scale and scope in the R&D process and it solves the appropriability problem but it (usually) prohibites R&D competition on the national level. Second, it gives the national carrier's interests a high priority in the development of equipment systems which may be a problem for the export activities of the manufacturers. On the other hand the manufacturers have the advantage to compete internationally on the basis of production costs because most of the development expenditure is financed by the national carrier[10].

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9 This problem is mentioned by Olley in the case of Bell Canada and Nothern Telecom, Olley, R.E.(1982), p. 187

10 The manufactures have to carry R&D costs for the adoption of the national equipment to the foreign network environment.

In the second model the carrier has a relative weak position. It has only small in-house R&D ressources. It is not involved in joint R&D activities and it does not finance R&D in the manufacturing sector directly but indirectly through the procurement of equipment. It gives the manufacturers an incentive to do specific R&D for its needs by restricting market participation to the winners of a first phase of a procurement procedure for a number of years. In this model, it depends on the price competition during the first years and the threat of potential competition thereafter to what extent the carrier pays for[11]. In this model economies of scale and scope cannot be realized as good as in the first model but there is R&D competition among the manufacturers. Manufacturers' interests and the market needs they face nationally and internationally have a higher priority. This can be an advantage in international markets. But they may have a disadvantage in international price competition. This depends on the price competition in their home market.

The above two models are of course idealizations and we do not observe them undiluted in reality. In particular, the national R&D systems in Europe and Japan are mixtures of them.

3. International comparison of R&D expenditure

Information concerning R&D expenditure have been collected from national sources of the most disparate kind. Owing to gaps and inconsistencies estimations were unavoidable. Therefore, the results should be interpretated as "soft" data and not as "hard" facts. The information concerning the structure of each national R&D budget is more reliable than the information about the absolute national R&D budgets in telecommunications.

Table 3/1 shows the estimated national R&D expenditures for telecommunications[12]. It is differentiated between expenditures in the military and in the civil sectors. R&D in the military sector is R&D for communications financed by the defence department and R&D for communications in military sector financed by the manufacturers. The military sector has to be included for two reasons. First, R&D for military communication

11 Due to the technological competition of the manufacturers it is possible that the carrier has to pay for the development of more than one system. Assume a closed economy and two independently developping firms. In such a case the carrier would have to pay for the development of two systems if there is no cross-subsidization involved and both firms survive. Economically speaking, this is the price the carrier has to pay for R&D rivalry in his home market which reduces his risk to pick the wrong system.

12 We have got the impression that the US and the German R&D budgets are overestimated while that of Japan is underestimated, but we have got no reliable information to what extent. The US Figure is based on R&D in SIC 366.

purposes can have spill-over effects for the development of equipment for civil use. Second, defence departments may fund R&D for communications equipment which can be directly used in the civil sector. The interviews of the Fraunhofer Institute provide examples of both effects, but it remained unclear how important these spill-over effects are. R&D in the military sector is large in the USA, France and the UK[13].

Table 3/1: National R&D expenditure for telecommuncations 1987[a)]

	USA	Japan	Germany	France	UK
1. R&D expenditure for telecommunications (billion US $)	13	4.4	2.4	1.9	2.1
a) in the military sector (billion US $)	5	0	0	0.9	0.7
b) in the civil sector (billion US $)	8	4.4	2.4	1.0	1.4
2. R&D expenditure for telecommunications in % of national R&D	10	10	10	11	13

a) Estimates based on national R&D statistics, government budgets and other sources. National currencies converted into US $ by current purchasing power parities used by the OECD for the field of science.

The USA has by far the largest R&D budget for telecommunications, but more than one third is financed by the defence department (Table 3/1). Overall, the proprotions of the national R&D budgets are in line with the proportions of the national GNPs[14]. In the civil sector, Japan's R&D expenditure is relatively large compared to that of the USA. This may be an advantage for Japanese firms in the future[15].

All countries spend an astonishing large share of their national R&D budget on telecommunications. It varies from 10 % to 13 %.

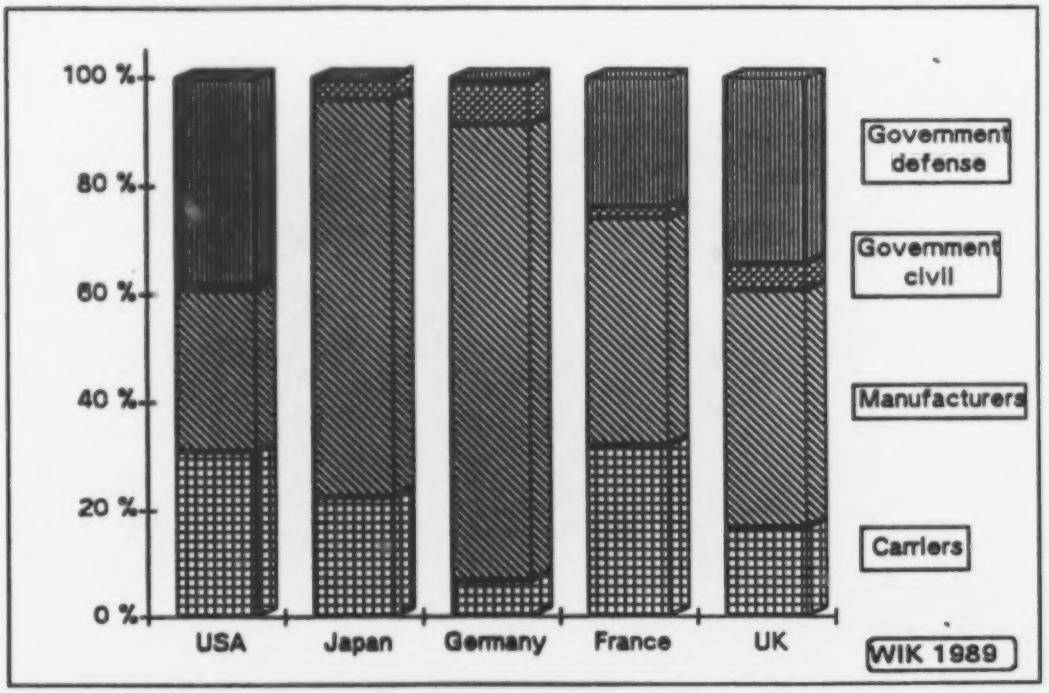
13 Government military R&D expenditure as share of the whole national R&D budget in 1986: USA 38%, UK 24%, France 20%, Germany 6% and Japan 2%. Source: Fraunhofer-Institut für Systemtechnik und Innovationsforschung, Karlsruhe

14 The proportions of GNPs in 1986 are USA 100, Japan 40, Germany 21, France 17 and UK 16.

15 This is also the case for Germany. But we have the impression that R&D in the military sector is under-estimated in Germany and that some of it is included in the civil sector.

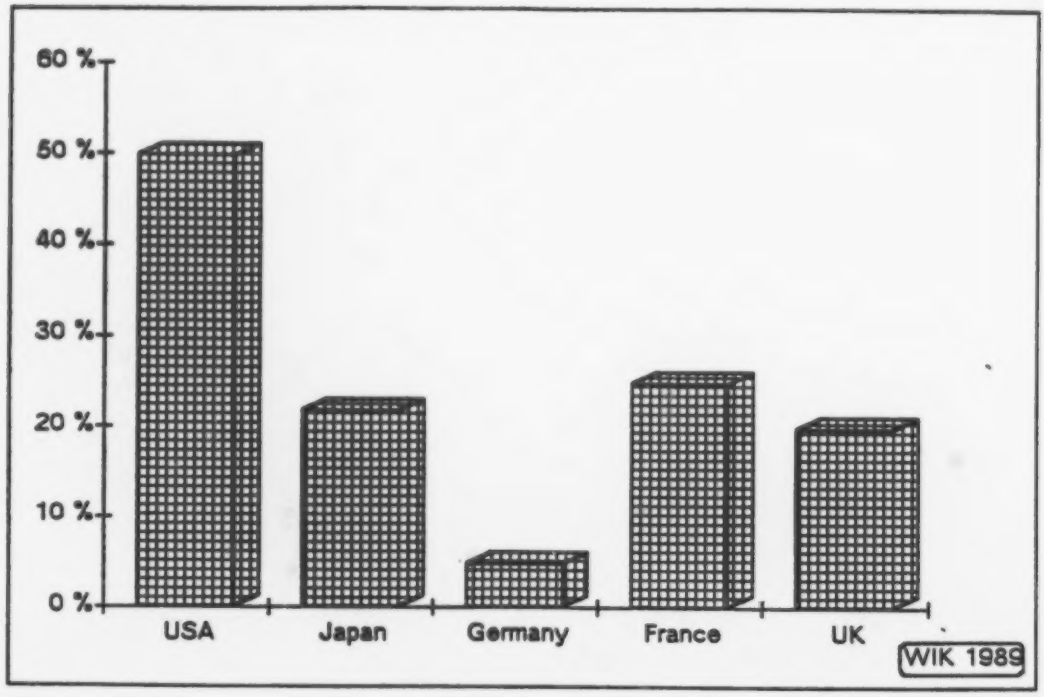
Figure 3/1 shows how the national R&D budgets are financed by sectors. Government defence departments have a large share in the USA, the UK and France. All governments subsidize R&D in the information technology to some extent. Money goes to universities, research institutes or manufacturers. The share of civil government money is relative small in all countries. Germany has got the highest, but we expect that there is some money from the defence department included.

Figure 3/1: Sources of funds for telecommunications R&D 1987



Carriers usually have a strong influence on the civil telecommunications R&D. They perform R&D and they finance R&D in universities, in research institutions and in the manufacturing sector. In the USA, carriers perform half of the national R&D budget (Figure 3/2). This is not surprising because the vertically integrated carriers ATT and GTE are counted as carriers. Therefore, the US situation cannot be directly compared to the other countries where carriers are not vertically integrated.

Figure 3/2: R&D performance of carriers in percentage of civil telecommunications R&D 1987



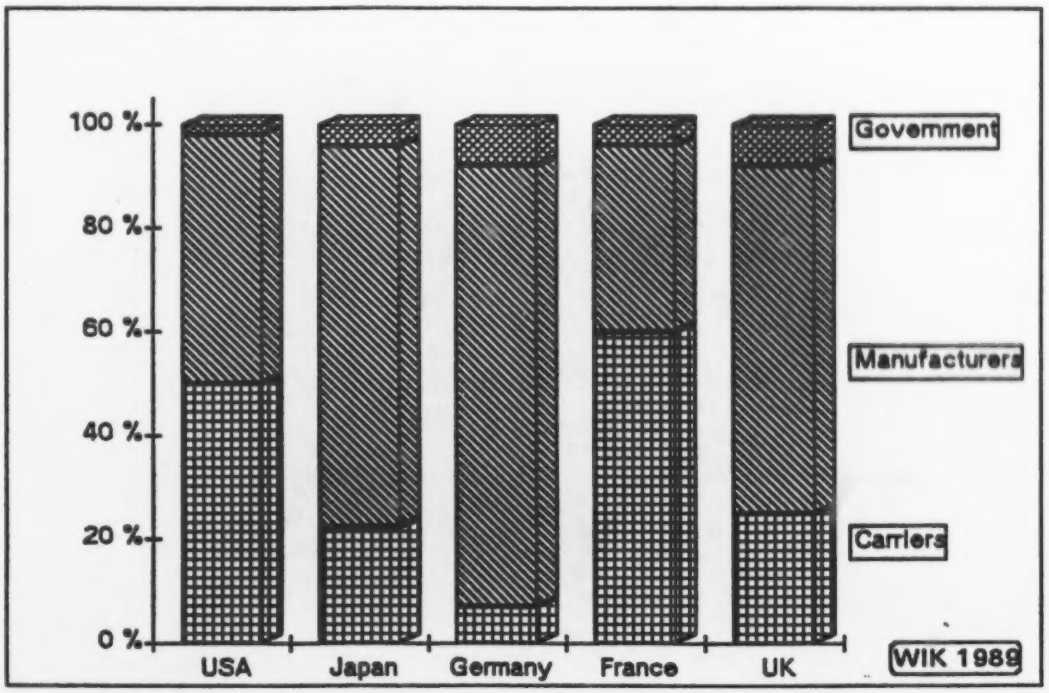
In France, Japan and the UK carriers are performing between 20 and 25 % of the national R&D, which gives them a strong direct influence on the national R&D system. Their position is particularly strong in research and long-term oriented development activities. Germany is the extreme case with a carrier that performes just 5 % of telecommunications R&D.

In the UK and especially in France carriers finance external R&D. Some money goes to universities and research institutions but most of it goes to the manufacturers. BT and France Telecom have a tradition of contract development arrangements with their national manufacturers. BT has reduced its joint development activities since the middle of the eighties, while France Telecom still finances almost half of the development activities of the manufacturers by development contracts. This gives France Telecom the leading role in the national R&D system. France Telecom finances an even higher proportion of the national R&D budget than the vertical integrated carriers in the USA (Figure 3/3).

In Germany, the carrier also finances some external R&D, but the amount is of minor importance. Internal and external R&D of the Deutsche Bundespost (DBP) account for less than 10 % of the national R&D.

The structures of the national R&D budgets indicate that France and Germany are the extreme cases in the one or other direction, respectively, regarding the direct influence of carriers on national R&D - i. e. in the case of not vertically integrated carriers (Figure 3/3).

Figure 3/3: Sources of funds for civil telecommunications R&D 1987



Manufacturers finance most of the national R&D expenditure in Germany, Japan and the UK[16]. This leaves the manufacturing sector with a great influence on R&D in these countries on the one hand but also with a financial burden and risk on the other. Both aspects can have effects on international competitiveness. It is interesting to recognise

16 For Japan and Germany, this is in line with aggregated national R&D numbers. In the case of the UK the result is surprising. Especially because the dominant manufacturers GEC and Plessey report that the share of their own funded R&D is just 40 % and 30 % of their whole R&D budget. But these numbers refer to all business areas.

that the often stated leading roles of the government (MITI and MPT) and NTT in the Japanese R&D system is not based on financial flows but other mechanisms.

Table 3/2 shows the R&D expenditures of carriers in the five countries. AT&T has by far the largest R&D resources and the highest R&D intensity measured by R&D per turnover. NTT's R&D expenditure is just one third of AT&T's. France Telecom and NTT have the highest R&D intensity within the group of not vertically integrated carriers. The Deutsche Bundespost has the lowest. The Regional Bell Operating Companies (RBOCs) are in the middle.

Table 3/2: Carriers R&D activities in 1987[b)]

Carrier	Internal and external R&D in Mio. US $[c)]	R&D per turnover in %	R&D personnel
AT&T[a)]	2 600	7.3	26 000
NTT	940	3.8	6 000
RBOC (incl. Bellcore)	910	1.5	6 000
France Telecom	603	4.1	4 300
BT	330	2.1	3 300
GTE	250	1.6	1 800
Deutsche Bundespost	168	1.1	1 800
KDD	25	2.0	190

a) APT included
b) Estimates based on annual reports and interviews
c) National currencies converted into US $ by current purchasing power parities used by the OECD for the field of science

The numbers indicate that AT&T, NTT, France Telecom and the RBOCs are important players in the global R&D activities.

Table 3/3 shows estimate of the R&D expenditures of the ten largest telecommunications equipment manufacturing companies. They all belong to the countries studied in this paper with the exception of Ericsson from Sweden and Northern Telecom from Canada. Many of the companies have diversified business interests

outside the telecommunications business. They perform R&D for all their business areas and usually do not publish R&D numbers seperately for the telecom sector. Therefore, the numbers are rough estimates.

Table 3/3: R&D expenditures of major manufacturing company groups for civil telecommunications in 1987[a)]

Rank	company group	Telcom-equipment turnover in billion US $	in % of total turn-over	R&D for telecom in million[b)] US $	R&D intensity of the company group in %
1	AT&T (with APT)	11.9[c)]	29	2 600	7.3
2	Alcatel[d)]	8.2	79	800	10.0
3	Siemens[d)]	5.1	24	650	12.5
4	NEC[d)]	4.1	32	106	10.0
5	Northern Telecom	4.8	100	588	12.1
6	Ericsson[d)]	3.3	90	300	9.9
7	Motorola	3.1	52	270	7.8
8	GEC/Plessey (GPT)[d)]	2.3	19	437 (210)	3.8 (12)
9	Fujitsu[d)]	1.6	16	130	8.0
10	GTE	2.0	13	251	1.6

a) Estimates
b) In some cases rough estimations
c) "Sale of products"
d) National currencies converted into US $ by current purchasing power parities used by the OECD for the field of science

AT&T has by far the largest R&D budget followed by Alcatel, Siemens and Northern Telecom. The R&D budget of NEC is not plausible, it seems to be too low.

4. International comparison of patents

R&D is a process with different stages and R&D expenditure is only the input side of it. More R&D input does not necessarily mean better R&D results. Better R&D results of a company or a country does not necessarily mean better competitiveness and higher market share. But in high technology sectors such as telecommunications, R&D expenditure and R&D results seem to be a necessary condition for future market success. Patents can be interpreted as an intermediate output of R&D which is especially related to development activities and therefore relatively close to the market. An increasing patent activity in a certain area of technology may be interpreted as an indicator for future market activities and success.

Therefore the Fraunhofer Institut for Systemtechnik and Innovationsforschung (ISI) has analysed patent activities in the telecommunications sector and subfields of it. This analysis was based on patent applications at the US and the German patent offices from 1975 to 1986. The assumption is that the situations on the US and the German markets are representative of the international situation. To exclude patents of minor quality the analysis was limited to patent applications for foreign markets because those patents involve higher costs for the applying company. For international comparisons ISI has developped an indicator for the "relative technological position" (RTP) of countries[17]. It is compiled as an index which is set equal to one for Germany in 1975. Patents can give protection for more than one year. Therefore it is sensible to cumulate patents for a number of years to indicate the "patent potential" (PP) which has been accumulated by a country. Because the percentage of patents which are not prolonged increases drastically after five years ISI has accumulated the RTPs for five years. The patent potential PP5 shows the technological potential of a country as an index[18].

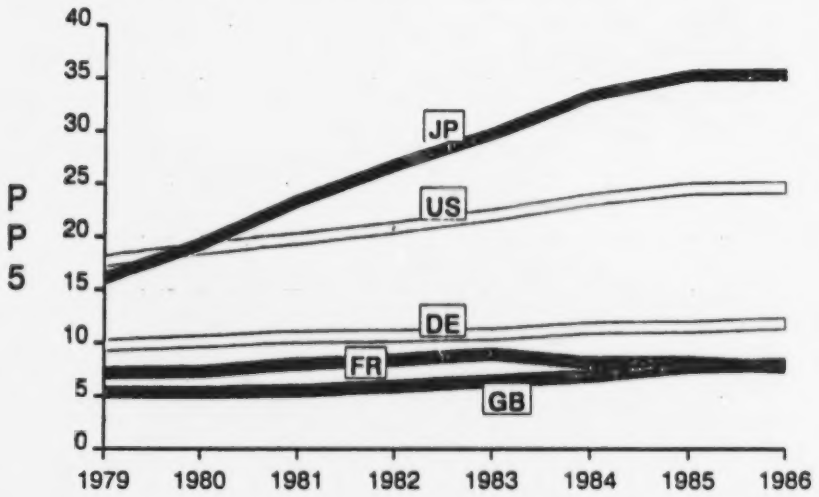
In the following, the PP5 indicator is used to compare patent activities in the USA, Japan, Germany, France and the UK in the telecommunications sector and in certain subfields of it.

Figure 4/1 shows the development of the technological potential for the whole telecommunications sector from 1979 to 1986. We observe moderate increases of the patent activities in the European countries, larger increases in the USA. But the most striking feature is the dynamic development of Japanese patent activities. The Japanese patent potential overtook that of the USA in 1980. Its increase leveled of in the middle

17 For definitions see Schmoch, 1988, p 56ff
18 Grupp, H., Schnöring, Th. (ed.), Forschung und Entwicklung im Telekommunikationssektor - internationaler Vergleich mit zehn Ländern, chapter 11 (forthcoming)

of the eighties, but by this time it was about 40 % higher than that of the USA. To judge by this indicator, Japan has thus taken the lead in telecommunications development activities and has accumulated the largest stock of proprietary knowledge in this field of technology. Japan is far ahead of the USA. Germany has the lead in Europe, but the European countries are far behind the USA and Japan.

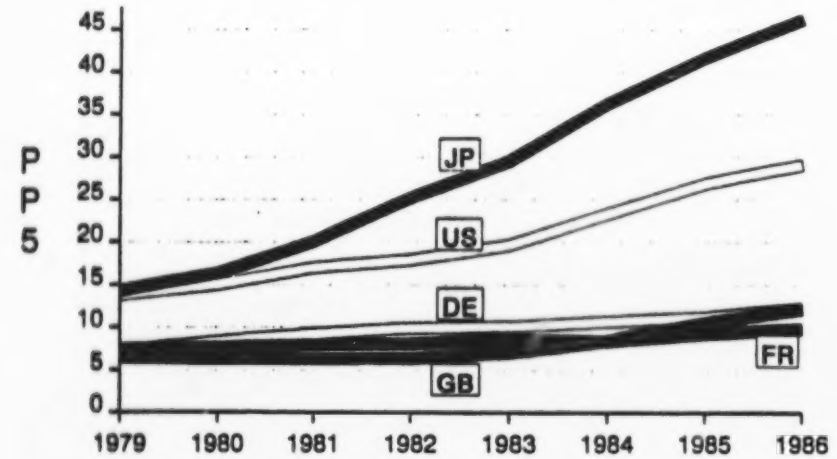
Figure 4/1: Technological potential in telecommunications 1979 - 1986



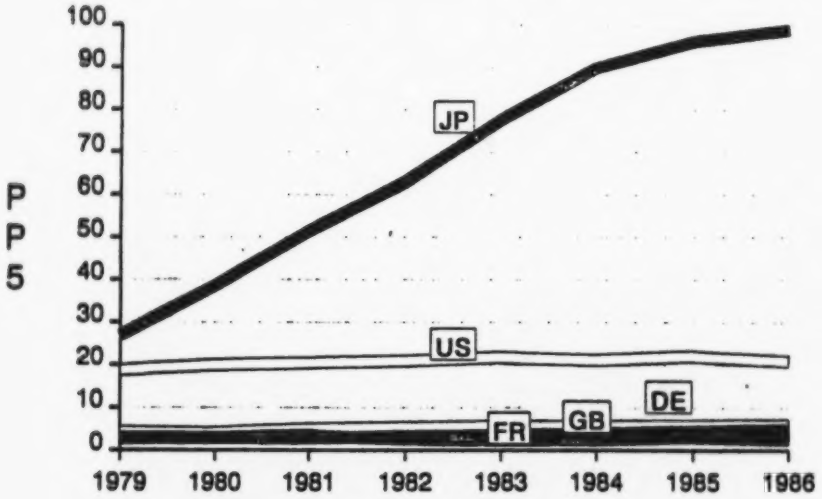
a) Japan = JP; United States of America = US; Germany = DE; France = FR; United Kingdom = GB

Japanese patent activities have been particularly dynamic in certain subfields of telecommunications: optical communications (optical cables, optical semiconductor elements etc.), image communication (facsimile, picture telphone etc.) and general picture transmission (TV-systems, HDTV etc.). Their technological world leadership position seems to be strong in these areas (Figure 4/2).

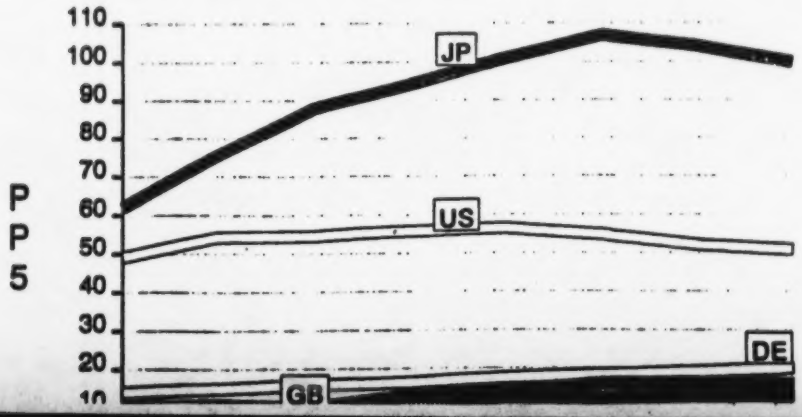
Figure 4/2: Technological potential 1979 - 1986
- optical (fibre) communication -



- image communication -



- general picture transmission -



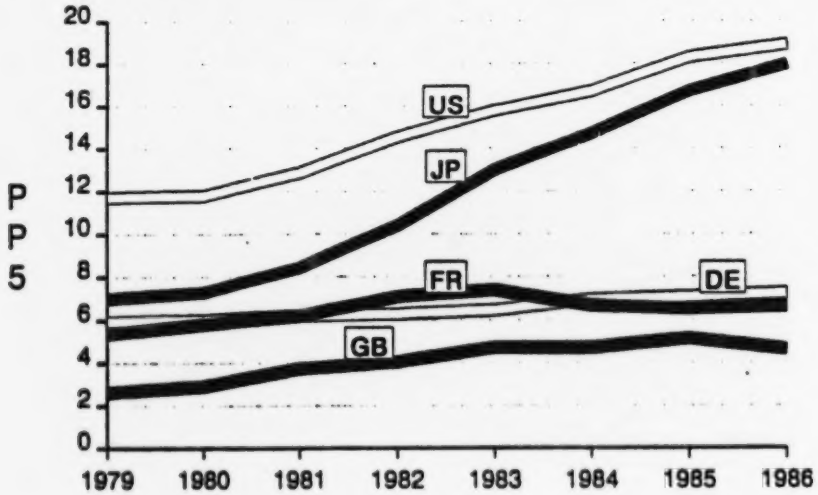
This impression is consistent with other findings: A study of the US National Science Foundation from 1988 revealed an increasing lead of Japan for R&D in fiber optics compared to the USA[19]. Japanese manufacturers have a very strong lead in the global facsimile market. At present, facsimile equipment is the major export product of the Japanese telecommunications equipment industry[20]. A third indication is that Japanese firms (NEC and Fujitsu) have captured almost one third of the US optical fiber electronics market[21].

The USA still has the lead in other subfields of telecommunications. One is the high frequency telemetry field which is closely related to the military sector. But there are other sectors as well: grid based (wire) communications, radio technique and digital transmission (Figure 4/3). Japan has been catching up in digital transmission and Germany has lost ground in grid based (wire) communications.

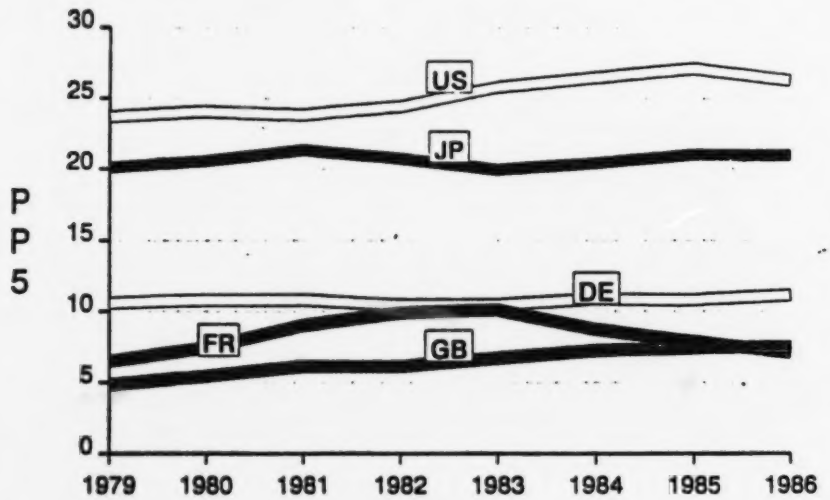
19 The Wall Street Journal, 17 Nov. 1988
20 The share of facsimile equipment in Japanese total telecommunications equipment export (wire and radio communications equipment) was 20% in 1985 and 45% in 1988.
21 Salomon Brothers, Telecommunications equipment, the US market, 1987

Figure 4/3: Technological potential 1979 - 1986

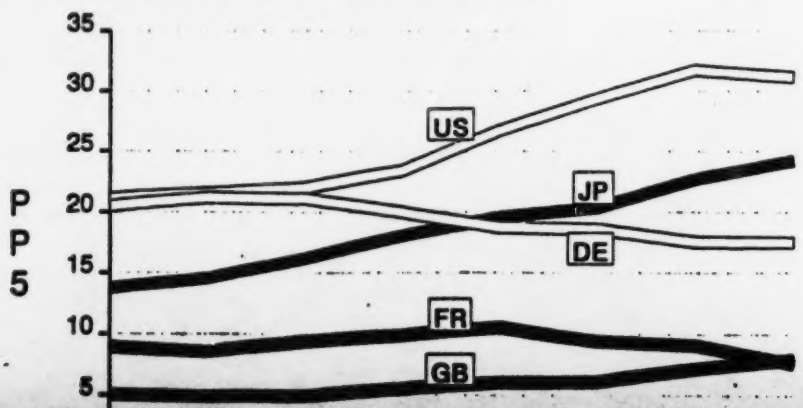
- digital transmission -



- radio technique -



- grid based (wired) communication -



Overall, the analysis of patent activities has one message: Japan has invested a lot of resources in building up technological potentials in the telecommunications sector. It has acquired a very large stock of proprietary knowledge in all areas of telecommunications and has taken the leading positions (from the USA) in a number of economically interesting technological fields. Corresponding market successes can already be observed in some markets closely associated with those technological fields.

There remains an open question: Can Japan, based on this large stock of proprietary knowledge, take the lead in other market segments as well? The answer to this question is partly related to the question of patentability of R&D results. Software and systems engineering know-how can hardly become subject of a patent but both are very important elements of R&D and market success in telecommunications. In this respect, patents have a deficit as indicator for future market success in market segments like central office switches and large PABXs.

It is often said that Japan has a lag in software development and systems engineering. The US National Science Foundation assesses a lag of Japanese R&D in "telecommunication networks" compared to the USA[22] and Japans international market position in the switching market is relatively weak up to now[23]. This lag should give some time to European and US competitors in markets for complex telecommunication products. But it is one major objective of Japan's current R&D policy to upgrade the country's software development capabilities. If Japan succeeds in this, then Japanese manufacturers will be strong competitors in all telecommunications market segments based on their large stock of proprietary knowledge.

5. Characteristics of the national R&D systems

In this chapter, some basic characteristics of the national R&D systems are outlined. The analysis is focused on the general roles of government, carriers, manufacturers, and universities.

5.1 Japan

How can the dynamic and successful R&D activities in Japan be explained?

22 The Wall Street Journal, 17 Nov. 1988
23 Switching equipment (central office and PABX) accounts for only 7% of Japans telecommunications equipment exports. This share has been stable since 1985.

The Ministry of Trade and Industry (MITI) and the Ministry of Post and Telecommunications (MPT) have a substantial influence on telecommunications R&D. The influence is not so much based on government funding of R&D (Figure 3/1) but on the creation of a complex structure of collaborative R&D activities of NTT, manufacturers, and research institutions. The ministries use a varity of instruments. Recent examples are the R&D program "Telecommunications Frontier Project" (TFP), the Japan Key Technology Center (KTC) and the Advanced Telecommunications Research Institute (ATR)[24].

These programs and projects create collaborative R&D activities of NTT, manufacturers and public research institutions in certain fields of technology for a limited number of years. Projects are often performed in a single lab and the participants delegate R&D personnel. This rotation of staff seems to be an effective mechanism to share existing know-how and to transfer the results of projects back to the companies. The programs generate a sort of common technological background. They have medium and long-term oriented R&D objectives and exclude product development. Product development is done competitively among the manufacturers. From an economic and Western perspective it is astonishing that competing companies are willing to share their R&D resources to such an extent as they do not get proprietary knowledge for their R&D investment[25].

Since the liberalisation of the telecommunications market and the privatisation of NTT the MPT has developped a stronger commitment to long term oriented R&D and has gained influence on national R&D policy in telecommunications. MPT has enlarged the scope and the resources of its own Communications Research Lab (CRL), it has started TFP and became partner of MITI in KTC and ATR. This may be interpreted as a reaction of the regulatory body to compensate NTT's tendency towards a more market oriented R&D strategy.

NTT, the major carrier in Japan, has large R&D resources (Table 3.2). In the past, NTT had in practice industrial policy obligations which may have resulted in an over-

[24] Japan Key Technology Center (KTC) was found in 1985 by MITI and MPT. It is an institution which shall promote basic research in Japan. KTC establishes research institutions. One example is the Advanced Telecommunications Research Institute (ATR) which was found in 1987. ATR has about 200 people R&D staff and performs long term oriented research. ATR is funded by KTC and by private companies. The personnel comes from NTT, telecommunications manufacturers and other companies. Some researches come from abroad. Telecommunications Frontier Project (TFP) is a R&D program MPT started in 1988. It is a program to promote collaborative research of NTT, manufacturers and research institutions. It is designed similar to the famous large scale projects which MITI has created in the early eighties. MPT's Communications Research Lab is coordinating the project.

[25] Some European countries and the European Commission have tried to develop similar programs for "pre-competitive" R&D.

investment of R&D. Its R&D intensity is a lot higher than that of other not vertically integrated carriers. Approximately half of NTT's 6000 R&D staff is working in eleven laboratories. One lab does basic research, the others do applied research and long-term development in certain areas[26]. The other half of the R&D staff is engaged in development activities mainly for software and services[27]. This indicates on the one hand that NTT has large development resources but that NTT is also strongly committed to research and long-term R&D activities[28]. Almost one third of all Japanese scientific publications in telecommunications comes from NTT while the company's share of Japanese patents is just 2 %. This is another indicator for NTT's commitment to research and its leading role in the national research community. It remains unclear to what extent the new competitive environment of NTT will limit its willingness and its resources for research in the future. NTT has decentralized some of its development staff to the service divisons.

Japan's manufacturers finance and perform almost three quarters of the national R&D. NEC, Fujistu, OKI and Hitachi, the so-called Denden-family with traditionally strong relations to NTT, are the leading companies but other well-known electronic companies are engaged in telecommunications R&D as well. It is a charcteristic of most Japanese equipment manufacturers that they all have diversified business interests in the electronics market.

Japan's manufacturers have a strong and broad commitment to long-term oriented R&D. About 5 % of their R&D budget is for basic research and 20 % is for applied research. One third of the scientific publications in telecommunications comes from manufacturers. The publications of the leading companies cover a broad spectrum in telecommunications while the activities of the remaining companies are more focused on particular fields within telecommunications. All companies are engaged in government R&D programs and projects.

The manufacturing sector holds 95 % - 98 % of the patents which indicates that most of the development is done in this sector.

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26 The labs are named: Basic Research Lab (approx. 160 people), Applied Electronics Lab (370), Opto-electronics Lab (240), LSI Lab (240), Software Lab (400), Radio Communication Systems Lab (200), Transmission Systems Lab (200), Communication Switching Lab (230), Human Interface Lab (230), Communications and Information Processing Lab (470), Telecommunication Netzworks Lab (200). This gives an indication of the wide range of NTT's research activities

27 NTT has got a Network Systems Development Center with (approx.) 820 people and a Software Development Center with 1750 People. The rest of the development personell is in the service divisions.

28 This interpretation seems fairly safe although the definition of what "research" is differs among the countries.

It is not totally clear how NTT and the manufacturers cooperate in the development of complex equipment systems, for example central office switches. NTT's procurement policy says that NTT cooperates with competent manufacturers in the development of equipment which is not available in the market and which needs a lot of special development for NTT's network. In practice this seems to mean that NTT is engaged in joint development of equipment systems with the members of the Denden-family. It is not known that NTT pays seperately for the development activities of the manufacturers. Development costs are included in the product price. This procedure gives NTT's needs a high priority in the development of complex telecommunications systems. This can be a problem for the international competitivness of Japanese manufacturers because the systems may not be so well suited for foreign markets with their different needs[29]. But they have a cost advantage because NTT uses substantial own R&D resources for the joint development projects.

Universities do some research in telecommuncations but their major role is in education. Two public research institutes outside the university system are important for the government's R&D policy and the whole R&D system: MITI's Electrotechnical Lab (ETL) with 175 people in telecommunications research and MPT's Communications Research Lab with 430 people.

Overall the Japanese R&D system in telecommunications is a complex structure of collaboration of all sectors which realizes a substantial amount of economies of scale and scope. The collaborative approach is particularly strong in research and long-term development, competitive elements are stronger in development activities close to the market. The carrier NTT performs a lot of research and is engaged in joint development with the major manufacturers. The dominant role of NTT may be a problem for export activities on the one hand but it gives Japanese manufacturers a cost advantage on the other. MPT has established itself as a major player in government R&D policy beside MITI. The complex structure of R&D collaboration in Japan can be described shortly as government guided national R&D strategy.

[29] It may be that this effect is part of the explanation why Japans international market success in telecommunications equipment has been mainly limited to customers premises equipment so far. Japans telecommunications equipment exports in 1988 consist to 45 % of fascimile equipment and to 11 % of telephones and telephone application equipment. Switching equipment (central office and PABX) had a constant share 7-8 % since 1985. The increase in exports of 30 % (1985 to 1988) is almost totally due to the facsimile boom.

5.2 USA

The Pentagon finances more than one third of the national telecommunications R&D budget (Table 3.1). Its projects are primarily for telecommunications equipment for military use. Spill-over effects to equipment for civil use are likely but they can not be quantified. There is a growing tendency in the USA to use Pentagon R&D programs for industrial policy purposes in the civil sector (SEMATECH and HDTV). For satellite communications, NASA programs are important. Beside that, the US government is not directly involved in the civil telecommunications R&D system[30].

The carriers AT&T, Regional Bell Operating Companies (RBOCs) and GTE perform half of the civil telecommunications R&D (Table 3.1). AT&T has the largest R&D resources for telecommunications in the world (Table 3.3). Predictions that AT&T would reduce its R&D investment (especially its world-famous research capacity in Bell Labs) after the divestiture have not come true. AT&T's total R&D investment has even increased and the research organization at Bell Labs remained roughly the same size[31]. The RBOCs have created a new research entity, Bell Communications Research (Bellcore). Bellcore is owned by the seven RBOCs and their operating companies, and performs applied research and other technical services for them. It is about 40 % of the size of Bell Labs. The development of Bellcore was promoted by staff transfers from the old Bell System. Recently, some RBOC's started to build up their own R&D capacities besides Bellcore. Overall the research as well as the development expenditures for telecommunications have increased substantially as a consequence of divestiture[32]. The predicted negative impact of divestiture on the US R&D input which was based on the appropriability argument has not occured. The more competitive market environment seem to have stimulated R&D activities.

The RBOCs invest "only" about 1,5 % of their turnover in R&D. In the USA the question has been raised if this is not an underinvestment in R&D[33]. Such a conclusion is mainly based on a comparison with the R&D intensity of manufacturing companies and vertically integrated carriers like AT&T. In absolute numbers, the RBOCs' combined R&D budget is the third largest of any carrier worldwide. It has almost the size of NTT's R&D budget which is the largest of any carrier within the group of not

30 Government [illegible] telecommunications policy and the regulation of the industry naturally have indirect effects on [illegible] performance of AT&T and the RBOCs.

31 Noll, M. [illegible]

32 Noll [illegible] nearly 60% for the combined R&D expenditure of AT&T and Bellcore in 1989 over [illegible] level of 1982. The research organization of Bell Labs had 1249 people in [illegible] had 1191 people and Bellcore's applied research group had 498 people. [illegible] research people. Noll (1987) p. 178

33 See for example [illegible] p. 177

vertically integrated carriers. But the RBOCs' R&D intensity is relatively low among this group, only the Deutsche Bundespost has a lower one (Table 3/2).

AT&T, the RBOCs and GTE are the most important players in the US R&D system but there are other established manufacturers and a growing number of new manufacturers with R&D resources. The new entrants into the telecommunications market use R&D investment as a strategic weapon and have on average higher R&D intensities than the incumbants[34]. Patents and publications in telecommunications from US sources show that the national R&D activities are widely spread over many entities. AT&T holds the first rank, but with only 11 % of the publications (1986) and 14 % of the patents (USPTO 1984)[35]. The ten-firm concentration ratio of patents in the USA is 43 %, while that of Japan is 60 % (DPA/EPA 1985). This indicates a relatively wide-spread distribution of development activities in the USA.

The USA has a diversified infrastucture of public research institutes in telecommunications. Universities and research institutions such as Rand Corporation do research in telecommunications. From an international perspective, their work is relative closely related to industry R&D activities[36].

Overall, the US R&D system for civil telecommunications has been shaped by its big market and by a relatively large number of carriers and manufacturers which do R&D. From a worldwide perspective, the carriers, especially AT&T, have large research as well as development resources. The government is not directly involved in civil telecommunications R&D, but indirectly over Pentagon funds for R&D.

5.3. France

In France the defence department finances a substiantial share of the national telecommuncations R&D budget which has potential spill-over effects on civil telecommunications. The French government uses the national carrier France Telecom for its industrial policy. France Telecom has to finance government R&D programs for the whole information technology sector. The financial burden from this has been sometimes even higher than France Telecom's R&D expenditure for

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34 Dowling, M.J. (1988), Strategic investments in innovation: The telecommunications equipment industry, 1975 - 1986, University of Texas at Austin, p. 49 f.

35 RCA Corporation, ITT, Motorola, GTE, General Electric Company, Zenith, IBM and Westinghouse Electr. Company had the most patents after AT&T (USPTO 1984).

36 In 1986, 29 % of the US publications in telecommunications came from US universities, 6 % from research institutions. In 1984, the research institutions hold 10 % of US patents in the US market, in the German market their share has been only 1 % in 1985.

telecommunications. French governments have a long tradition in industrial policy and France Telecom as part of the administration must be seen in this context.

The French R&D system in civil telecommunications has a relatively simple structure. France Telecom is the dominant entity, with the largest R&D budget of any European carrier and a R&D intensity which is higher than NTT's (Table 3/2). France Telecom's "Centre National d'Etudes des Telecommunications" (CNET) performs most of the national research in telecommunications and finances some external research. CNET also performs long-term oriented development activities for telecommunications systems. Beside that, France Telecom's procurement agency finances about 45 % of the development in the manufacturing sector directly by development contracts. CNET specifies and controls the contents of the development contracts while the business aspects of these contracts are handled by the procurement agency. The manufacturing of the equipment is procured seperately according to detailed specifications of France Telecom. The specifications are based upon CNET's R&D activities and the results of the development contracts.

Although France Telecom is financing directly most of the development it holds less than 10 % of the French patents while the manufacturers hold almost 80 %. This indicates that the proprietary rights gained in the development activities go predominantly to the manufacturers.

The manufacturing sector is highly concentrated with the Alcatel Group as leading company. Alcatel has got by far the largest R&D expenditure in civil telecommunications[37]. Universities and research institutes are of minor importance for civil telecommunications R&D[38].

The French R&D system realizes a large amount of economies of scale and scope. France Telecom's leading role (even in equipment development) causes a tendency to allocate the national R&D resources dominantly according to the needs of the national carrier. This may be a problem for the international competitivenes of the manufacturers and their equipment[39]. On the other hand they have a cost advantage because the national carrier pays for the development separately.

[37] Alcatel's R&D expenditure in telecommunications in France is about twice as much as that of the following four equipment manufacturers (SAT, TRT, Matra and Jeumont-Schneider) together.

[38] In 1986, 18 % of the French publications in telecommunications came from Universities and 15 % from research institutes.

[39] The French manufacturers have raised this point in the interviews.

In the future, the French model may come under pressure from two sides. First, the creation of Alcatel NV due to the aquisition by CGE/Alcatel of the European telecommunications companies of ITT in 1987 has shifted the economic interests of the leading French manufacturer substantially to European markets. In 1987, close to three quarters of Alcatel NV's turnover was outside of France[40]. Alcatel NV has the potential to become a truely international corporation with R&D activites in many European countries. To achieve this, Alcatel will have to orientate its R&D strategy to the needs of all its major customers and not only to the needs of France Telcom. This will be a new situation for France Telecom and may question its leading role in the French R&D system. Second, France Telecom will come under increasing pressure to liberalize its procurement for carriers equipment. The European Commission has an interest to act this way as well as the governments of the other European countries with a national equipment industry and a different system of R&D funding. From this perspective it is possible that France Telecom will reduce its direct engagment in development activities.

5.4 United Kingdom

The situation in the UK is similar to the French in some respects. The Ministry of Defence (MoD) finances a large share of the telecommunications R&D budget (Table 3/2). MoD gives money to the industry and has its own research institutes. There are indications for spill-over effects but it is not possible to assess their importance[41]. Some British experts have claimed that the large influence of MoD on R&D in the British electronics industry has had a negative impact on the industry's success in civil markets because it has orientated scarce R&D resources towards market niches.

The British government also finances R&D programs in information technology for the civil sector. The programs are supposed to initiate collaborative research activities among industry, research institutes and universities. Some of the projects belong to the telecommunications sector but financially the programs are of minor importance[42].

Up to the middle of the eighties British Telecom (BT) had a dominant role in the national R&D system for civil telecommunications comparable to that of France Telecom. This has changed to some extent. BT has a large R&D budget and 3300 R&D staff (Table 3/2). The company finances 25 % of the national R&D for civil

40 In 1985 the Alcatel Group had roughly 40% of its turn over in foreign markets. In 1987 Alcatel NV had 70% of its turn over outside of France.

41 The interviews in the UK have given some examples for spill-over effects of MoD projects in mobile radio communication. See also, Financial Times, August 15, 1989

42 One example is a program called "Joint Optoelectronic Research Systems" with a budget of 64 Mio. $ for the years 1986 to 1989.

telecommunications and it carries out 20 % of it. BT and its British Telecom Research Laboratory account for 19 % of the British publications in telecommunications (1986) and 18% of the British patents (EPA/DPA 1985). BT finances research in universities (5 % of BT's R&D expenditure 1987).

For a long time, BT had a strong direct influence on the equipment development in the manufacturing sector. BT had been engaged in joint development programs with the national manufacturers GEC, Plessey and STC and had development contracts with these companies. Problems in the joint development of the central office switch, System X, and the privatization of BT have lead to a gradual withdrawl of BT from such joint development projects. BT has also reduced its development contracts with the national industry[43]. BT's procurement policy has been opened for technological competition. BT has moved to a policy of second sourcing for central office switches, and in general, BT does not specify the equipment it procures to that extent as it used to do.

Recently, BT has changed its internal R&D funding. The new system gives the commercial divisions more influence on R&D programs. One may expect that this will give short and medium-term objectives and telecommunications services a higher priority in the R&D programs.

The structure of the British manufacturing sector is changing rapidly. It has been highly concentrated with GEC and Plessey as leading companies. Both have merged their telecommunications divisions into one company, GEC Plessey Telecommunications (GPT), in 1988. GPT is clearly dominating the British equipment market[44]. At present, Plessey is subject to a hostile take-over bid from GEC and Siemens. GEC and Plessey sell most of their telecommunications equipment in the UK[45]. Due to the joint development programs with BT, their R&D activities have been mostly orientated towards BT and the home market. With the problems of the System X development and BT's (consequent) policy change, GPT seems to have lost the international technological race in the central office switch market. BT has suggested to the Monopolies and Mergers Commission that without GPT forming an alliance with another manufacturer it would be very difficult, if not impossible, to maintain a significant British presence in public switching in the 1990s[46]. This can be taken as an open acknowledgement of the

43 BT still finances the upgrading of the software of System X by a development contract with GPT.
44 Monopolies and Mergers Commission (1989), The General Electric Company plc, Siemens AG and the Plessey Company plc, p. 33
45 The export ratio of GEC in "telecommunications and business systems" was 6 % in 1988 and Plessey's in "telecommunications" only 3 %, while the export ratio of Siemens in "telecommunications networks and security systems" was 23 % for example.
46 Monopolies and Mergers Commission (1989), p. 34

failure of the old joint development approach of BT and the national manufacturers under BT's leadership.

British universities do a considerable amount of research in telecommunications (32 % of the national publications 1986) but their work is not very closely related to industry needs.

5.5 Germany

In Germany, the defence department is not an important fanancier of R&D. Government R&D policy is done by the Federal Ministry for Research and Technology (FMRT). In telecommunications, the FMRT has funded R&D for satellites as part of programs for space technology, mainly in collaboration with France, and the FMRT has also programs for R&D programmes in telecommunications. One major objective of the programs was to secure the international competitiveness of the German industry. The FMRT mainly funded R&D for optical communications technology, switched-broadband communications, the introduction of a very sophisticated data communication network for the science community and R&D for high definition television. The funds for these programs were of minor importance compared to the national telecommunications R&D budget[47]. Half of it went to public research institutes and universities, the other half to the industry. The FMRT activities have helped medium and long-term R&D activites in the industry to some extent and they had a positive impact on the innovation activity of the Deutsche Bundespost, especially at the end of the seventies[48].

The most striking feature of the German R&D system is the insigificant role of the national carrier Deutsche Bundespost (DBP). The DBP has a research institute with roughly 340 people[49]. Its main objective is to provide the carrier with an independent judgement of technological developments, and it is involved in international standardization activities. The DBP has approximately 1500 people engaged in development activities. These people are not involved in the development of equipment but in development activities for new networks and services. Overall the DBP performs only 5 % of the national R&D budget (Figure 3/2). It finances some external research mainly at universities and it procures equipment for pilot applications. Therefore, the

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47 In the [illegible] the FMRT spent on average 40 mio. $ per year but since 1985 the ministry has reduced its engagement drastically to roughly 24 mio. $. The whole national R&D budget for [illegible] was 2.4 billion $ in 1987 (Table 3/1).

48 [illegible] (1989), FuE-Förderung des Bundesministeriums Forschung und Technologie im [illegible]bereich, Wissenschaftliches Institut für Kommunikationsdienste, Diskussions-[illegible]munikationsforschung Nr. 51, Bad Honnef.

49 [illegible] has hardly increased during the last 20 years.

DBP finances a higher share of the national R&D budget (7 %) than it performs (5 %) but it is still quite low compared to that of other countries (Figure 3/3).

Up to the end of the seventies the DBP had relative close and stable relations with a small group of national manufacturers. It followed a strict policy of standardization which meant that no more than one system or one typ of equipment for any given application was procured. This limited the amount of technological competition and gave the largest manufacturer Siemens a leading position in the R&D process. In those days the DBP was relative closely involved in the definition of new systems. During the seventies this system failed in the development of a new generation of public switching equipment (EWS) which beside other factors provided an incentive to change the old system. The DBP introduced R&D rivalry among the manufacturers and restrained further direct involvement in detailed technical specification of new systems. The new procurement systems give an incentive to do specific R&D for the needs of the DBP by restricting the market for a number of years to those manufacturers which survive the first two stages of a procurement process. In the first stage, the vendors present pilot equipment which is tested by the DBP and the second stage is a price competition among the successful vendors for a certain amount of equipment.

The DBP pays for R&D costs of the systems in the course of the actual procurement of the equipment. R&D costs are part of the price calculation of the vendors. Therefore, the amount of money the DBP pays for R&D depends on the competitive situation during the first years when a new system is introduced and the threat of potential competition thereafter[50].

In 1979, when the DBP introduced this new procurement procedure for digital public switching equipment, the participation was limited to vendors who would develop and produce the switches predominantly in Germany. This has changed. The procurement process for digital access cross-connector systems which started in 1988 was open to any vendor, and foreign manufacturers are taking part.

In such a system it is not astonishing that the manufacturers perform (over 90 %) and finance (87 %) almost all the R&D activities (Figure 3/2). Siemens is the leading German telecommunications manufacturer with large R&D resources (Table 3/3) but

[50] The procurement systems are different, respectively, for switching system equipment, transmission equipment, etc. but the basic principles are the same. They were developped in 1979 for the procurement of digital switches. Siemens, Standard Electric Lorenz (SEL, German company of ITT, now Alcatel) and Philips Kommunikations Industrie (PKI) took part in the first phase. PKI failed and the DBP is introducing EWSD (Siemens) and SYSTEM 12 (SEL/ITT). Both systems perform well in international markets.

there are a number of other manufacturers with substantial R&D capacities. Standard Electric Lorenz (SEL) and Philips Kommunikations Industrie (PKI) are part of large multinational telecommunications and electronic companies, Alcatel and Philips, with large international R&D resources. The Bosch Group is establishing itself in telecommunications and AEG has a long tradition in the market[51]. The number of technological independent manufacturers seems to be relative large compared to other European countries.

Many universities and a number of public research institutes do research in telecommunications (34 % of the national publications in 1986). The FMRT finances a specialized research institute, the Heinrich Hertz Institut, with more than 250 people.

6. Conclusions

Differing national R&D policies in general and distinct regulations and market structures in the telecommunications sector have created R&D systems that look quite different from each other. This in the past was sustainable because of the relatively isolated situation of each national market. Liberalisation of the telecommunications markets, however, brings pressure on the old national divisions of labour in R&D.

In all countries the government is - directly or indirectly - involved in the telecommunications R&D system. In the USA, France and the UK, the governments finance R&D for communications equipment for military use which may have spill-over effects to equipment for civil use. In Japan, Germany and the UK, the government finances R&D programs directly oriented towards civil telecommunications but the amount of money involved is small compared to the national R&D budgets. The Japanese government has a particularly strong influence on civil telecommuncations R&D through its government guidance of the R&D activities of carriers and manufacturers. In France, the government has a strong influence by the dominant role of France Telecom and its industrial policy objectives. All these government policies tend to create market distortions.

The role of the carriers differs substantially between the countries. According to our estimations, they perform and finance from 7 % of the civil telecommunications R&D budget in Germany up to 60 % in France. This situation can have a strong impact on the

[51] In 1985, Siemens had 24 % of the patents submitted by German companies to the German patent office (DPA), SEL 5 %, Philips subsidiaries 6 %, Bosch 16 % and AEG 6 %. In 1986, these firms' shares of the publications by all German entrants were: 22 % for Siemens, 7 % SEL, 5 % for Philips subsidiaries, 6 % for Bosch and 3 % for AEG.

international competitiveness of the manufacturers because they have to baer very different R&D costs. As long as the national equipment markets were closed the different systems had no consequences. Carriers which did not financed R&D directly had to pay for it (indirectly) with the price of the equipment. But the situation changes when the carriers equipment markets are liberalized. Manufacturers which have to baer R&D expenditure themselves have a disadvantage compared to manufacturers which get all their R&D expenditure or a substantial part of it directly paid by the carrier. Therefore - ceteris paribus - German manufacturers would loose the competition with French manufacturers in a totally liberalized European equipment market for carrier equipment as long as France Telecom holds on to its R&D system.

Of course, reality is more complicated than such simple models and so are predictions of the outcome of a total liberalization of the carriers equipment market in Europe. Market success depends not only on R&D funding but on R&D efficiency, production, marketing and service as well, and considerable entry barriers for telecommunications systems (like R&D for the adoption of the systems, marketing facilities and a service network) limit the amount of international competition anyway. But the observed differences of the national R&D systems are certainly a problem for the European Commission in their attempt to create a liberalized European carriers equipment market. We would expect that at least some harmonization of R&D financing between Germany and France will be a precondition for any further liberalization of the carriers equipment market in the European Community.

From a more general perspective we have two questions. First, the question of advantages and disadvantages of vertical integration for R&D in telecommunications. There are theoretical arguments for both sides[52]. Empirically, we observe vertical integration or quasi vertical integration in most countries but there has been no market test of this structure so far. With the liberalization of the telecom markets the situation has changed to some extent. Divestiture has seperated the RBOCs from the manufacturing sector. In Europe, BT and the Deutsche Bundespost have loosened their relation with the national manufacturers in R&D and many carriers started a policy of second sourcing from foreign manufacturers. In principle, this development opens market opportunities for foreign manufacturers but there is not enough empirical evidence to answer the first question.

The second question concerns the competitive situation of not-vertically-integrated manufacturers when their vertically (or quasi vertically) integrated competitors have a

52 See chapter 2.

monopoly or dominant market position on the service side? In such a situation, the "service division" can cross-subsidize the "manufacturing division" by overinvesting in R&D. But it is difficult to know what the "service division" should spend on R&D under normal market conditions and what is an overinvestment. This shows that the liberalization of the service market and the R&D policy of the dominant carriers are closely related to the liberalization of the carriers' equipment market. The different national approaches on the service market and the distinct R&D policies of carriers (and governments) are obstacles to a liberalization of the carriers equipment market.

The most interesting and perhaps most challenging country of our comparision is Japan. The Japanese R&D system with its complex structure of collaboration and competition of all sectors under the guidance of MPT, MITI and NTT differs substantially from that of all other countries. The system realizes substantial economies of scale and scope in the R&D process at the national level. During the last ten years, Japan has invested a great amount of resources in R&D for telecommunications. It has acquired a large stock of proprietary knowledge in telecommunications and has taken the leading position from the USA in a number of fields which are important for the future development. If the country succeeds in its attempt to up-grade its software and systems engineering capabilities it is quite likely that Japanese companies will become strong competitors to US and European companies in all telecommunications equipment market segments, not only in the customers premises equipment market.